

A WORKING MAN'S ANALYSIS OF INCIDENTS AND ACCIDENTS WITH  
EXPLOSIVES AT THE LOS ALAMOS NATIONAL LABORATORY, 1946-1997

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## INTRODUCTION

Contemporary knowledge of a significant incident or accident involving energetic material improves the safety environment. A large fraction of the work force at Los Alamos from the time period when large amounts of experimental work involving explosives was done have retired and there has been a loss of the contemporary knowledge. While the amount of experimental work has decreased there is still significant experimental and production work being performed. At the inception of the Laboratory, hectic and intense work was the norm during the development of the atomic bombs. After the war the development of other weapons for the Cold War again contributed to an intense work environment. Formal Standard Operating Procedures (SOPs) were not required at that time. However, the occurrence of six fatalities in 1959 during the development of a new high-energy plastic bonded explosive (94% HMX) forced the introduction SOP's. After an accident at the Department of Energy (DOE) plant at Amarillo, Texas in 1977, the DOE promulgated the Department wide *DOE Explosives Safety Manual*. Table I outlines the history of the introduction of SOPs and the *DOE Explosives Safety Manual*. Many of the rules and guidelines presented in these documents were developed and introduced as the result of an incident or accident. However, many of the current staff are not familiar with the background of the development. To preserve as much of this knowledge as possible, we have collected documentation on incidents and accidents involving energetic materials at Los Alamos.

Formal investigations of serious accidents elucidate the multiple causes that contributed to accidents. These reports are generally buried in a file, and are not read by more recent workers. Reports involving fatalities at Los Alamos before 1974 were withheld from the general employee. Also, these documents contain much detail and analysis that is not of interest to the field worker. We have collected the documents describing 116 incidents and have analyzed the contributing factors as viewed from the standpoint of the individual operator.

All the incidents occurred at the Los Alamos National Laboratory and involved energetic materials in some manner, though not all occurred within the explosive handling groups. Most accidents are caused by multiple contributing factors. We have attempted to select the one or two factors that we consider as the most important relative to the individual doing the work. The value of SOP's was an obvious conclusion *a priori*. The introduction and use of SOPs reduced the probability of serious accidents. The second conclusion was less obvious in that it appears that the SOP did not adequately provide all the controls necessary for 16% of the events. Violations of SOP's, always considered as a potential contributor, was assigned as the major contributor in only 10 incidents.

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## ANALYSIS OF INCIDENTS

We have collected the documentation from 116 incidents starting in 1946 through 1997. It assuredly does not represent all the incidents that have occurred, since many were not documented. However, we believe that they do present a reasonable picture of the type of incidents that have occurred and are likely to occur again if the knowledge is lost. Four

<b>TABLE I</b> <b>History of Safety Controls Involving</b> <b>Energetic Materials At Los Alamos National Laboratory</b>	
1947	“Intent” of Army Ordnance Safety Manual
1956	TiN <sub>3</sub> Explosion (1 fatality)
1958	GMX Division Explosive Safety Committee (to review explosive development)
1959	Explosive drilling accident (2 fatalities)
1959	Suggestion to incorporate SOPs
1959	Burning Ground accident (4 fatalities)
1959	Approved SOPs required to recommence work
1961	Three Phase Development Program started
1980	Explosive Safety Committee reports to Laboratory Director
1982	DOE Explosives Safety Manual published

levels of categorization were assigned to each incident. These were; 1) Type of operation, 2) Status of the control provided by the SOP, 3) Factors contributing to the event, with a limit of two factors for each incident, and 4) Consequence of the incident.

Twelve types of operations were identified. Table II identifies the types together with the number found for the various operations. Though it could not be verified, we believe that there was more attention given to formal reporting from the operating groups responsible for chemical operations, assembly, disassembly, pressing, processing, and transportation than from the firing groups. Also during the period just prior to and following a 1991 DOE “Tiger Team” inspection more attention was paid to incident reporting and documenting accidents. These effects would bias any detailed study within each type of operation or incident rates as a function of time.

<b>TABLE II</b> <b>TWELVE TYPES OF OPERATIONS WERE IDENTIFIED</b>	
ASSEMBLY AND DISASSEMBLY	6 incidents
CHEMICAL OPERATIONS	8 incidents
FIRING OPERATIONS	31 incidents
INDUSTRIAL ACCIDENTS	2 incidents
MACHINING	23 incidents
MAINTENANCE	1 incident
MISCELLANEOUS	3 incidents
PRESSING	12 incidents
PROCESSING	13 incidents
RESTRICTED AREA CONTROL	5 incidents
TRANSPORTATION	6 incidents
WASTE DISPOSAL	6 incidents

The term “status of the SOP” is used to identify whether an SOP existed for the operation, was being followed, was inadequate, was violated, or was not required. Early in the development of the Laboratory, SOPs were not required. Table III presents the five categories into which the data were divided based on the status of the applicable SOP, along with an example of each, and the number of events in each category. The division into these categories was arbitrary with an indistinct line as to what the operator knew or did not know at the time, whether the actual operation was described and permitted or disallowed, or whether the operation needed to be covered with an SOP at the time of the incident. These five categories illustrate the application, understanding, and need for SOP’s in operations within a research environment.

The next stage of analysis was to assign a factor that caused the incident, with an arbitrary limit of two factors per incident. The attempt has been made to analyze the incident from the viewpoint of the individual performing the operation. We found that seven factors could be defined to describe all the events, though this required inserting an elliptical peg

**TABLE III**  
**CATEGORIZATION OF INCIDENTS BY STATUS OF SOP**

<b>STATUS OF APPLICABLE SOP CONTROLS</b>	<b>EXAMPLE</b>	<b>Number of Incidents</b>
Incident occurred within the bounds of an existing SOP. The outcome, including minor injuries and equipment loss was considered acceptable.	An explosion occurred in one cell of a die during a remote pressing operation. Approximately 40,000 pellets had been pressed previously with this die assembly. There was no explanation of the cause. (6/11/52)	25
Incident occurred with the bounds of an existing SOP. The event was previously unrecognized, more violent than expected, or did not proceed as planned.	A shot was fired after the ready fire switch was activated but before the "FIRE" button had been activated. All personnel were in the bunker, per the requirements of the SOP. (1/4/91)	41
Incident occurred outside the bounds of an existing SOP, or the SOP was inadequate to cover the event.	An air dryer was used to remotely warm a shot. It was inadvertently left on when hydrogen gas was turn on for the shot. The hydrogen ignited and then ignited the explosive. The flow valve was outside the bunker and outside the direct line of sight. The operator had to leave the bunker to turn of the gas. (12/4/86)	19
Incident occurred as the result of a violation of an SOP	An operator was carrying a charge in each hand and dropped one. It broke in three pieces. The incident may have been caused by a loose rug. (11/20/85)	18
Incident occurred before an SOP was required.	Worker fell from firing chamber while attempting to remove, by hand-pulling, a leveling screw from a piece of wood. He fell ten feet onto a concrete slab. (2/1/61)	13

in a round hole in some cases. Limiting the factors emphasizes the few important characteristics of incidents that need to be controlled. There is no doubt that other individuals analyzing the same data might make different assignments. However, we believe that ours presents a reasonable representation of the factors contributing to the incident. Table IV presents the seven factors that were identified with an example of each.

Severity of the consequences of the incident was categorized into the four levels identified in Table V together with an example of each. The first was that no damage or injury beyond that considered as a potential within the context of the SOP. This definition was created to allow for small incidents involving synthesis of new explosive materials and for misfires during the final countdown of test fire procedures. Personnel wear protective clothing during small-scale synthesis operations, but small minor injuries are a recognized consequence. With misfires during the final countdown, personnel are located within the firing bunker and the shot is lost, but with no potential for personnel injury. The next two levels involve equipment damage or personnel injury beyond the level considered as acceptable. The final level, considered as “severe,” involves significant personal injury(ies), equipment loss, or significant political damage to the project or the Laboratory. Also included in this level are incidents in which no one was injured but it is reasonable to assume that a serious injury was avoided only because the individual had the good fortune to be in a lucky location. Table VI and VII list the accidents and incidents that were assigned to the “serious” category.

## CONCLUSIONS

The most significant conclusion is the most obvious; the introduction and use of SOP’s and the later promulgation of the *DOE Explosives Safety Manual* reduced the probability of serious incidents, even if the SOP is inadequate. For 66 incidents where there was an existing SOP that was followed or where the event occurred outside an existing SOP only 3 were considered serious. There were four serious events in 19 incidents where it was considered that the SOP was inadequate. For 31 events in which there was a violation of an existing SOP or where there was no SOP there were 11 where the result was considered serious. One fatality involved an individual falling from a firing bunker and is considered as an industrial type accident. Other incidents for which there was a potential for a serious injury have also occurred since the introduction of SOPs.

The SOP was inadequate for 19 events. This is certainly a factor that should be considered in reviewing SOP for approval. A contributing factor apparent from the data is that overeagerness by the operator was considered as a major contributing factor in 17 incidents and that six of these resulted in serious events. Certainly training could improve the incidence of this factor.

A problem with a study of this type is that the data do not include all incidents. The study represents only those incidents that were documented. The assiduousness of providing written documentation and its accuracy varies both in time and with the operating group. Also there is a real hesitancy on the part of personnel to report incidents on the fear that a disciplinary action might be invoked. Some change in the safety environment and application that could improve the reliability of reporting even small incidents would provide a more accurate basis for studies such as this one.

**TABLE IV**  
**FACTORS CONTRIBUTING TO INCIDENTS INVOLVING ENERGETIC MATERIALS**

FACTORS	EXAMPLE	NUMBER OF INCIDENTS
Failure of Equipment	Detonator firing unit (CDU) fired when it reach approximately 5800 volts instead of holding at 6000 v. (6/15/78)	29
Inattention to controls or condition of equipment	During x-radiography of a piece of pressed TNT a dial thermometer was embedded in the piece. (10/2/61)	30
Overeagerness of personnel to proceed with experiment	An assembly was fired in a vessel designed to confine the detonation. The shot was realigned during final assembly and fragments penetrated the viewing ports. (7/24/97)	17
Error of commission or omission a preceding stage that was not covered in the operating procedure	The wrong information was supplied to firing team and shot information was lost. (11/13/85)	17
Lack of knowledge of material properties or equipment	An intermediate in a chemical synthesis was allowed to dry and when touched, the material exploded. (12/6/77)	30
Lack of training of operator	A fire occurred in a waste collection basket and later in a Dempster Dumpster. The incident was apparently caused by incorrect disposal of metallic lithium. (5/4/73)	13
The condition existed without the knowledge of operating personnel and knowledge was not normally expected of personnel	During an official visit by LANL employees to a DOD ordnance test range, an “unexploded ordnance” device (UXO) detonated under the tire of one vehicle. The area had been declared clear of “UXO’s.” (3/19/97)	8

TABLE V		
SEVERITY OF INJURIES AND DAMAGE RESULTING FROM INCIDENTS		
SEVERITY	EXAMPLE	NUMBER OF INCIDENTS
No injuries or property damage beyond that considered as potential within the context of the SOP	During a remote operation involving extrusion loading of uncured XTX into a plastic assembly the unit exploded. (2/18/64)	41
Minor equipment loss outside of that expected by the SOP	The operator was making a cut into explosive with a boring tool. The piece was shorter than expected and toll cut into the face of the chuck. (6/29/92)	52
Minor injuries outside that expected by the SOP	An unexpectedly rapid reaction occurred in a pressurized flask during an analytical procedure. The flask broke causing minor injuries to the operator. (4/20/77)	5
Serious injury(ies) or death, or the potential for these (except by luck), serious property damage, or potential serious political consequences for Laboratory.	Because of security compartmentalization a material was not identified chemically. It was placed in an oven with too high a heating rate and an explosion occurred. There was significant property damage and political consequence for the operating group. (11/14/96)	18

TABLE VI	
FATALITIES RELATED TO ENERGETIC MATERIALS AT LOS ALAMOS NATIONAL LABORATORY 1946-1997	
1946	1 Death, 2 Serious Injuries (Hand-made smoke bomb)
1956	1 Death, Explosion of Thallous Azide ( $\text{TlN}_3$ )
1959	2 Deaths, Drilling PBX 9404
1959	4 Death, Burning Ground Accident
1961	1 Death, Fall from Firing Bunker

The results of this study have been well received by both management and operating personnel within the explosive handling groups. We believe that the technique of analysis of incidents directly in the operational area can be used as an integral part of the safety training as it is based on events to which an individual can personally relate. The incidents all occurred within their work environment and in some cases they are aware of the event either contemporaneously or by word of mouth.

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TABLE VII	
OTHER INCIDENTS RANKED AS SERIOUS IN ANALYSIS	
1965	Re-entry to firing mound after 15 minutes with explosive still burning from a bullet sensitivity test
1975	Personnel exposed with fragment range
1975	Explosion in nitric oxide (NO) distillation unit
1977	Fragment fell in parking lot outside of cleared area.
1978	Personnel exposed within fragment range.
1981	H <sub>2</sub> - O <sub>2</sub> Explosion at gas cylinder supply area
1981	Solvent-Air/PETN Explosion
1982	Key switch by-passed, operator received 300 v shock
1984	Two visitors in cleared area when shot was fired
1989	Test unit detonation on firing mound
1991	Personnel exposed within fragment range
1995	Shot fired with control circuit in “by-pass” Mode
1996	Explosion of material during chemical analysis
1997	Vehicle carrying LANL personnel struck and initiated an unexploded ordnance device at a military test range